A POLICY ON

Geometric Design of Highways and Streets

2004

American Association of State Highway and Transportation Officials

Steep downhill grades can also have a detrimental effect on the capacity and safety of facilities with high traffic volumes and numerous heavy trucks. Some downgrades are long and steep enough that some heavy vehicles travel at crawl speeds to avoid loss of control on the grade. Slow-moving vehicles of this type may impede other vehicles. Therefore, there are instances where consideration should be given to providing a truck lane for downhill traffic. Procedures have been developed in the HCM (**14**) to analyze this situation.

The suggested design criterion for determining the critical length of grade is not intended as a strict control but as a guideline. In some instances, the terrain or other physical controls may preclude shortening or flattening grades to meet these controls. Where a speed reduction greater than the suggested design guide cannot be avoided, undesirable type of operation may result on roads with numerous trucks, particularly on two-lane roads with volumes approaching capacity and in some instances on multilane highways. Where the length of critical grade is exceeded, consideration should be given to providing an added uphill lane for slow-moving vehicles, particularly where volume is at or near capacity and the truck volume is high. Data in Exhibit 3-59 can be used along with other pertinent considerations, particularly volume data in relation to capacity and volume data for trucks, to determine where such added lanes are warranted.

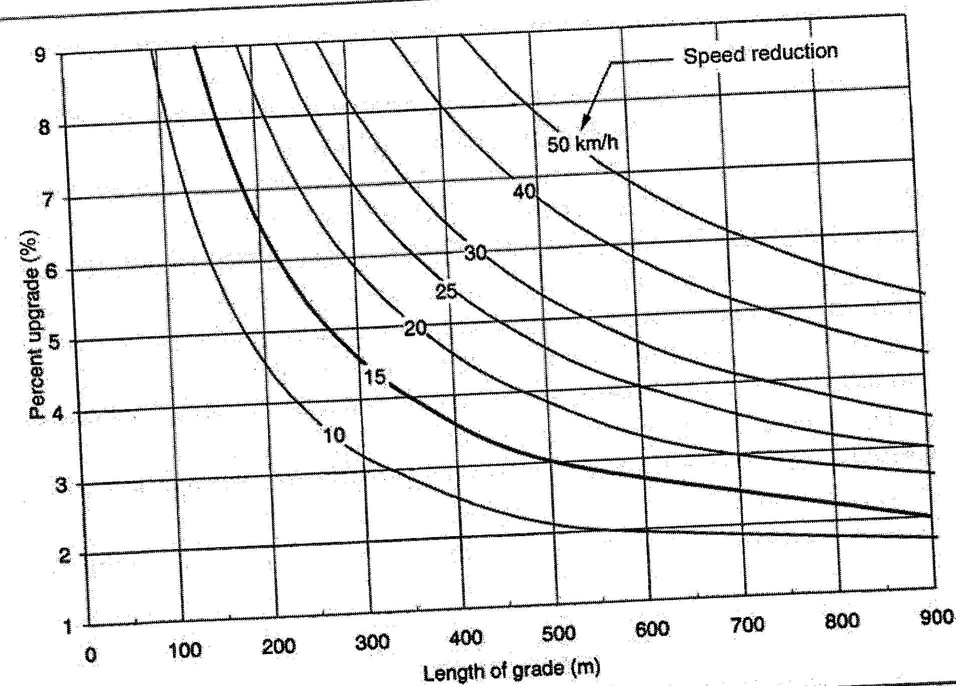
Climbing Lanes

Climbing Lanes for Two-Lane Highways

General. Freedom and safety of operation on two-lane highways, besides being influenced by the extent and frequency of passing sections, are adversely affected by heavily loaded vehicle traffic operating on grades of sufficient length to result in speeds that could impede following vehicles. In the past, provision of added climbing lanes to improve operations on upgrades has been rather limited because of the additional construction costs involved. However, because of the increasing amount of delay and the number of serious crashes occurring on grades, such lanes are now more commonly included in original construction plans and additional lanes on existing highways are being considered as safety improvement projects. The crash potential created by this condition is illustrated in Exhibit 3-58.

A highway section with a climbing lane is not considered a three-lane highway, but a two-lane highway with an added lane for vehicles moving slowly uphill so that other vehicles using the normal lane to the right of the centerline are not delayed. These faster vehicles pass the slower vehicles moving upgrade, but not in the lane for opposing traffic, as on a conventional two-lane road. A separate climbing lane exclusively for slow-moving vehicles is preferred to the addition of an extra lane carrying mixed traffic. Designs of two-lane highways with climbing lanes are illustrated in Exhibits 3-61A and 3-61B. Climbing lanes are designed for each direction independently of the other. Depending on the alignment and profile conditions, they may not overlap, as in Exhibit 3-61A, or they may overlap, as in Exhibit 3-61B, where there is a crest with a long grade on each side.

METRIC



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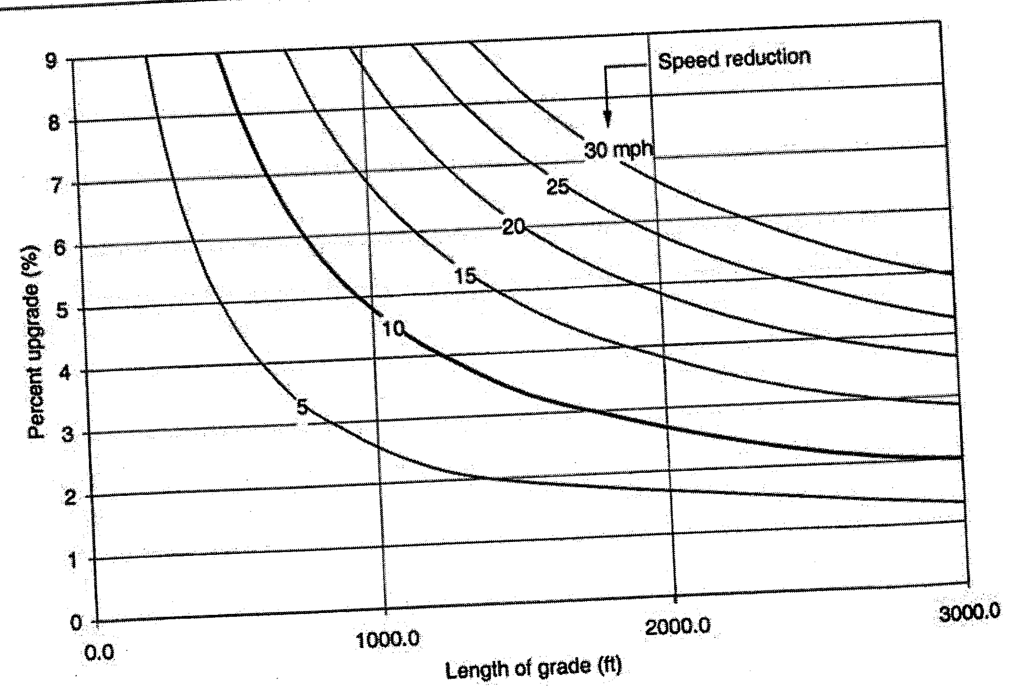

Exhibit 3-59. Critical Lengths of Grade for Design, Assumed Typical Heavy Truck of 120 kg/kW [200 lb/hp], Entering Speed = 110 km/h [70 mph]

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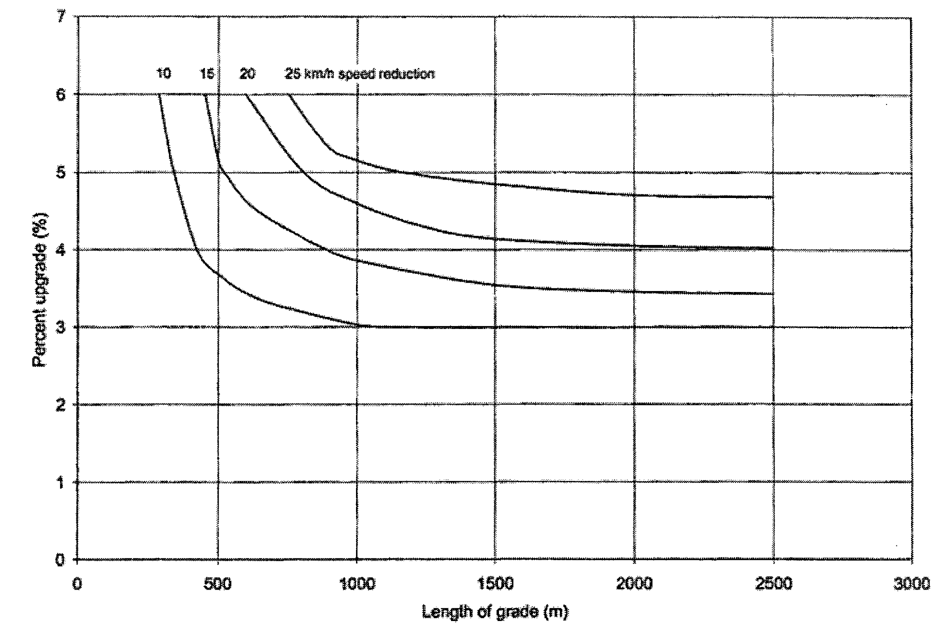

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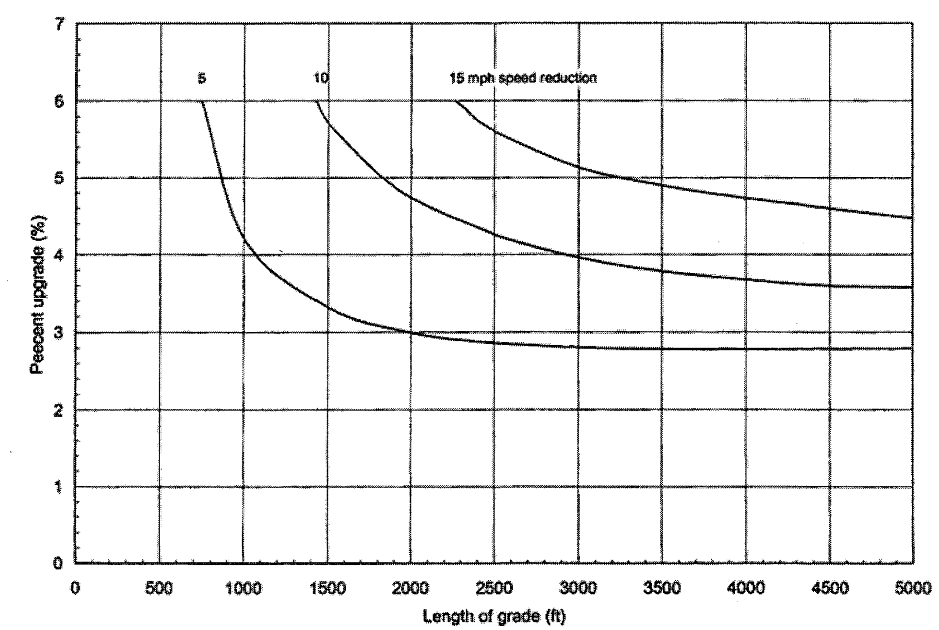

Exhibit 3-60. Critical Lengths of Grade Using an Approach Speed of 90 km/h [55 mph] for Typical Recreational Vehicle (40)

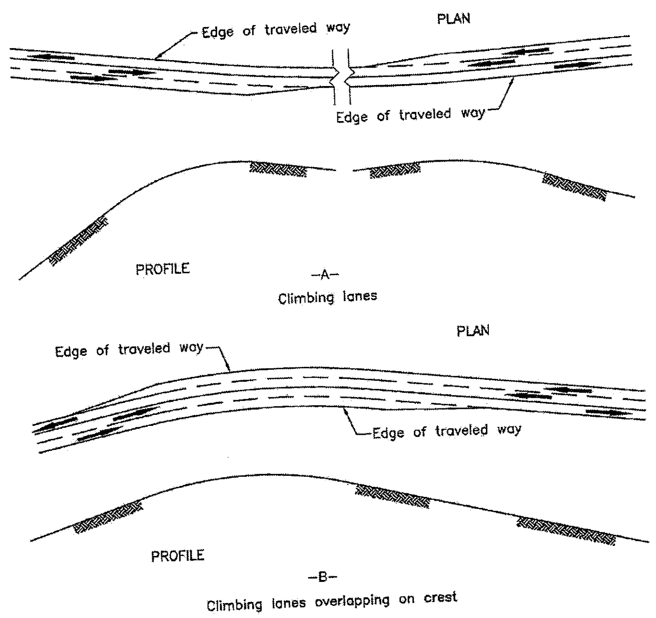

Exhibit 3-61. Climbing Lanes on Two-Lane Highways

It is desirable to provide a climbing lane, as an added lane for the upgrade direction of a two-lane highway where the grade, traffic volume, and heavy vehicle volume combine to degrade traffic operations from those on the approach to the grade. Where climbing lanes are provided, there has been a high degree of compliance in their use by truck drivers.

On highways with low volumes, only an occasional car is delayed, and climbing lanes, although desirable, may not be justified economically even where the critical length of grade is exceeded. For such cases, slow-moving vehicle turnouts should be considered to reduce delay to occasional passenger cars from slow-moving vehicles. Turnouts are discussed in the section on "Methods for Increasing Passing Opportunities on Two-Lane Roads" in this chapter.

The following three criteria, reflecting economic considerations, should be satisfied to justify a climbing lane:

1. Upgrade traffic flow rate in excess of 200 vehicles per hour.
2. Upgrade truck flow rate in excess of 20 vehicles per hour.
3. One of the following conditions exists:
   - A 15 km/h [10 mph] or greater speed reduction is expected for a typical heavy truck.
   - Level-of-service E or F exists on the grade.
   - A reduction of two or more levels of service is experienced when moving from the approach segment to the grade.

In addition, safety considerations may justify the addition of a climbing lane regardless of grade or traffic volumes.

The upgrade flow rate is determined by multiplying the predicted or existing design hour volume by the directional distribution factor for the upgrade direction and dividing the result by the peak hour factor (the peak hour and directional distribution factors are discussed in Chapter 2). The number of upgrade trucks is obtained by multiplying the upgrade flow rate by the percentage of trucks in the upgrade direction.

Trucks. As indicated in the preceding section, only one of the three conditions specified in Criterion 3 must be met. The critical length of grade to effect a 15 km/h [10 mph] truck speed reduction is found using Exhibit 3-59. This critical length is compared with the length of the particular grade being evaluated. If the critical length of grade is less than the length of the grade being studied, Criterion 3 is satisfied. This evaluation should be done first because, where the critical length of grade is exceeded, no further evaluations under Criterion 3 will be needed.

Justification for climbing lanes where the critical length of grade is not exceeded should be considered from the standpoint of highway capacity. The procedures used are those from the HCM (**14**) for analysis of specific grades on two-lane highways. The remaining conditions in Criterion 3 are evaluated using these HCM procedures. The effect of trucks on capacity is primarily a function of the difference between the average speed of the trucks and the average running speed of the passenger cars on the highway. Physical dimensions of heavy trucks and their poorer acceleration characteristics also have a bearing on the space they need in the traffic stream.

On individual grades the effect of trucks is more severe than their average effect over a longer section of highway. Thus, for a given volume of mixed traffic and a fixed roadway cross section, a higher degree of congestion is experienced on individual grades than for the average operation over longer sections that include downgrades as well as upgrades. Determination of the design service volume on individual grades should use truck factors derived from the geometrics of the grade and the level of service selected by the highway agency for use as the basis for design of the highway under consideration.

If there is no 15-km/h [10-mph] reduction in speed (i.e., if the critical length of grade is not exceeded), the level of service on the grade should be examined to determine if level-of-service E or F exists. This is done by calculating the limiting service flow rate for level-of-service D and comparing this rate to the actual flow rate on the grade. The actual flow rate is determined by dividing the hourly volume of traffic by the peak hour factor. If the actual flow rate exceeds the service flow rate at level-of-service D, Criterion 3 is satisfied. When the actual flow rate is less than the limiting value, a climbing lane is not warranted by this second element of Criterion 3.

The remaining issue to examine if neither of the other elements of Criterion 3 are satisfied is whether there is a two-level reduction in the level of service between the approach and the upgrade. To evaluate this criterion, the level of service for the grade and the approach segment should both be determined. Since this criterion needs consideration in only a very limited number of cases, it is not discussed in detail here.

The HCM (**14**) provides additional details and worksheets to perform the computations needed for analysis in the preceding criteria. This procedure is also available in computer software, reducing the need for manual calculations.

Because there are so many variables involved that hardly any given set of conditions can be properly described as typical, a detailed analysis such as the one described is recommended wherever climbing lanes are being considered.

The location where an added lane should begin depends on the speeds at which trucks approach the grade and on the extent of sight distance restrictions on the approach. Where there are no sight distance restrictions or other conditions that limit speeds on the approach, the added lane may be introduced on the upgrade beyond its beginning because the speed of trucks will not be reduced beyond the level tolerable to following drivers until they have traveled some distance up the grade. This optimum point for capacity would occur for a reduction in truck speed to 60 km/h [40 mph], but a 15 km/h [10 mph] decrease in truck speed below the average running speed, as discussed in the preceding section on "Critical Lengths of Grade for Design," is the most practical reduction obtainable from the standpoint of level of service and safety. This 15-km/h [10-mph] reduction is the accepted basis for determining the location at which to begin climbing lanes. The distance from the bottom of the grade to the point where truck speeds fall to 15 km/h [10 mph] below the average running speed may be determined from Exhibit 3-55 or Exhibit 3-59. Different curves would apply for trucks with other than a weight/power ratio of 120 kg/kW [200 lb/hp]. For example, assuming an approach condition on which trucks with a 120-kg/kW [200-lb/hp] weight/power ratio are traveling within a flow having an average running speed of 110 km/h [70 mph], the resulting 15-km/h [10-mph] speed reduction occurs at distances of approximately 175 to 350 m [600 to 1,200 ft] for grades varying from 7 to 4 percent. With a downgrade approach, these distances would be longer and, with an upgrade approach, they would be shorter. Distances thus determined may be used to establish the point at which a climbing lane should begin. Where restrictions, upgrade approaches, or other conditions indicate the likelihood of low speeds for approaching trucks, the added lane should be introduced near the foot of the grade. The beginning of the added lane should be preceded by a tapered section with a desirable taper ratio of 25:1 that should be at least 90 m [300 ft] long.

The ideal design is to extend a climbing lane to a point beyond the crest, where a typical truck could attain a speed that is within 15 km/h [10 mph] of the speed of the other vehicles with a desirable speed of at least 60 km/h [40 mph]. This may not be practical in many instances because of the unduly long distance needed for trucks to accelerate to the desired speed. In such situations, a practical point to end the added lane is where trucks can return to the normal lane without undue interference with other traffic—in particular, where the sight distance becomes sufficient to permit passing when there is no oncoming traffic or, preferably, at least 60 m [200 ft] beyond that point. An appropriate taper length should be provided to permit trucks to return smoothly to the normal lane. For example, on a highway where the passing sight distance becomes available 30 m [100 ft] beyond the crest of the grade, the climbing lane should extend 90 m [300 ft] beyond the crest (i.e., 30 m [100 ft] plus 60 m [200 ft]), and an additional tapered section with a desirable taper ratio of 50:1 that should be at least 180 m [600 ft] long.

A climbing lane should desirably be as wide as the through lanes. It should be so constructed that it can immediately be recognized as an added lane for one direction of travel. The centerline of the normal two-lane highway should be clearly marked, including yellow barrier lines for no-passing zones. Signs at the beginning of the upgrade such as "Slower Traffic Keep Right" or "Trucks Use Right Lane" may be used to direct slow-moving vehicles into the climbing lane. These and other appropriate signs and markings for climbing lanes are presented in the MUTCD (**6**).

The cross slope of a climbing lane is usually handled in the same manner as the addition of a lane to a multilane highway. Depending on agency practice, this design results in either a continuation of the cross slope or a lane with slightly more cross slope than the adjacent through lane. On a superelevated section, the cross slope is generally a continuation of the slope used on the through lane.

Desirably, the shoulder on the outer edge of a climbing lane should be as wide as the shoulder on the normal two-lane cross section, particularly where there is bicycle traffic. However, this may be impractical, particularly when the climbing lane is added to an existing highway. A usable shoulder of 1.2 m [4 ft] in width or greater is acceptable. Although not wide enough for a stalled vehicle to completely clear the climbing lane, a 1.2-m [4-ft] shoulder in combination with the climbing lane generally provides sufficient width for both the stalled vehicle and a slow-speed passing vehicle without need for the latter to encroach on the through lane.

In summary, climbing lanes offer a comparatively inexpensive means of overcoming reductions in capacity and providing improved operation where congestion on grades is caused by slow trucks in combination with high traffic volumes. As discussed earlier in this section, climbing lanes also improve safety. On some existing two-lane highways, the addition of climbing lanes could defer reconstruction for many years or indefinitely. In a new design, climbing lanes could make a two-lane highway operate efficiently, whereas a much more costly multilane highway would be needed without them.

Climbing Lanes on Freeways and Multilane Highways

General. Climbing lanes, although they are becoming more prevalent, have not been used as extensively on freeways and multilane highways as on two-lane highways, perhaps for the reason that multilane facilities more frequently have sufficient capacity to handle their traffic demands, including the typical percentage of slow-moving vehicles with high weight/power ratios, without being congested. Climbing lanes are generally not as easily justified on multilane facilities as on two-lane highways because, on two-lane facilities, vehicles following other slower moving vehicles on upgrades are frequently prevented by opposing traffic from using the adjacent traffic lane for passing, whereas there is no such impediment to passing on multilane facilities. A slow-moving vehicle in the normal right lane does not impede the following vehicles that can readily move left to the adjacent lane and proceed without difficulty, although there is evidence that safety is enhanced when vehicles in the traffic stream move at the same speed.

Because highways are normally designed for 20 years or more in the future, there is less likelihood that climbing lanes will be justified on multilane facilities than on two-lane roads for several years after construction even though they are deemed desirable for the peak hours of the design year. Where this is the case, there is economic advantage in designing for, but deferring construction of, climbing lanes on multilane facilities. In this situation, grading for the future climbing lane should be provided initially. The additional grading needed for a climbing lane is small when compared to that needed for the overall cross section. If, however, even this additional grading is impractical, it is acceptable, although not desirable, to use a narrower shoulder adjacent to the climbing lane rather than the full shoulder provided on a normal section.

Although primarily applicable in rural areas, there are instances where climbing lanes are needed in urban areas. Climbing lanes are particularly important for freedom of operation on urban freeways where traffic volumes are high in relation to capacity. On older urban freeways and arterial streets with appreciable grades and no climbing lanes, it is a common occurrence for heavy traffic, which may otherwise operate well, to platoon on grades.

Trucks. The principal determinants of the need for climbing lanes on multilane highways are critical lengths of grade, effects of trucks on grades in terms of equivalent passenger-car flow rates, and service volumes for the desired level of service and the next poorer level of service.

Critical length of grade has been discussed previously in this chapter. It is the length of a particular upgrade that reduces the speed of low-performance trucks 15 km/h [10 mph] below the average running speed of the remaining traffic. The critical length of grade that results in a 15-km/h [10-mph] truck speed reduction is found using Exhibit 3-59 and is then compared to the length of the particular grade being examined. If the critical length of grade is less than the length of grade being evaluated, consideration of a climbing lane is warranted.

In determining service volume, the passenger-car equivalent for trucks is a significant factor. It is generally agreed that trucks on multilane facilities have less effect in deterring following vehicles than on two-lane roads. Comparison of passenger-car equivalents in the HCM (**14**) for the same percent of grade, length of grade, and percent of trucks clearly illustrates the difference in passenger-car equivalents of trucks for two-lane and multilane facilities.

To justify the cost of providing a climbing lane, the existence of a low level of service on the grade should be the criterion, as in the case of justifying climbing lanes for two-lane roads, because highway users will accept a higher degree of congestion (i.e., a lower level of service) on individual grades than over long sections of highway. As a matter of practice, the service volume on an individual grade should not exceed that for the next poorer level of service from that used for the basic design. The one exception is that the service volume for level-of-service D should not be exceeded.

Generally, climbing lanes should not be considered unless the directional traffic volume for the upgrade is equal to or greater than the service volume for level-of-service D. In most cases when the service volume, including trucks, is greater than 1,700 vehicles per hour per lane and the length of the grade and the percentage of trucks are sufficient to consider climbing lanes, the volume in terms of equivalent passenger cars is likely to approach or even exceed the capacity. In

this situation, an increase in the number of lanes throughout the highway section would represent a better investment than the provision of climbing lanes.

Climbing lanes are also not generally warranted on four-lane highways with directional volumes below 1,000 vehicles per hour per lane regardless of the percentage of trucks. Although a truck driver will occasionally pass another truck under such conditions, the inconvenience with this low volume is not sufficient to justify the cost of a climbing lane in the absence of appropriate criteria.

The procedures in the HCM (**14**) should be used to consider the traffic operational characteristics on the grade being examined. The maximum service flow rate for the desired level of service, together with the flow rate for the next poorer level of service, should be determined. If the flow rate on the grade exceeds the service flow rate of the next poorer level of service, consideration of a climbing lane is warranted. In order to use the HCM procedures, the free-flow speed must be determined or estimated. The free-flow speed can be determined by measuring the mean speed of passenger cars under low to moderate flow conditions (up to 1,300 passenger cars per hour per lane) on the facility or similar facility.

Recent data (**14, 41**) indicates that the mean free-flow speed under ideal conditions for multilane highways ranges from 0.6 km/h [1 mph] lower than the 85th percentile speed of 65 km/h [40 mph] to 5 km/h [3 mph] lower than the 85th percentile speed of 100 km/h [60 mph]. Speed limit is one factor that affects free-flow speed. Recent research (**14, 41**) suggests that the free-flow speed is approximately 11 km/h [7 mph] higher than the speed limit on facilities with 65- and 70-km/h [40- and 45-mph] speed limits and 8 km/h [5 mph] higher than the speed limit on facilities with 80- and 90-km/h [50- and 55-mph] speed limits. Analysis based on these rules of thumb should be used with caution. Field measurement is the recommended method of determining the free-flow speed, with estimation using the above procedures employed only when field data are not available.

Where the grade being investigated is located on a multilane highway, other factors should sometimes be considered; such factors include median type, lane widths, lateral clearance, and access point density. These factors are accounted for in the capacity analysis procedures by making adjustments in the free-flow speed and are not normally a separate consideration in determining whether a climbing lane would be advantageous.

For freeways, adjustments are made in traffic operational analyses using factors for restricted lane widths, lateral clearances, recreational vehicles, and unfamiliar driver populations. The HCM (**14**) should be used for information on considering these factors in analysis.

Under certain circumstances there should be consideration of additional lanes to accommodate trucks in the downgrade direction. This is accomplished using the same procedure as described above and using the passenger-car equivalents for trucks on downgrades in place of the values for trucks and recreational vehicles on upgrades.

Climbing lanes on multilane roads are usually placed on the outer or right-hand side of the roadway as shown in Exhibit 3-62. The principles for cross slopes, for locating terminal points, and for designing terminal areas or tapers for climbing lanes are discussed earlier in this chapter in conjunction with two-lane highways; these principles are equally applicable to climbing lanes on multilane facilities. A primary consideration is that the location of the uphill terminus of the climbing lane should be at the point where a satisfactory speed is attained by trucks, preferably about 15 km/h [10 mph] below the average running speed of the highway. Passing sight distance need not be considered on multilane highways.

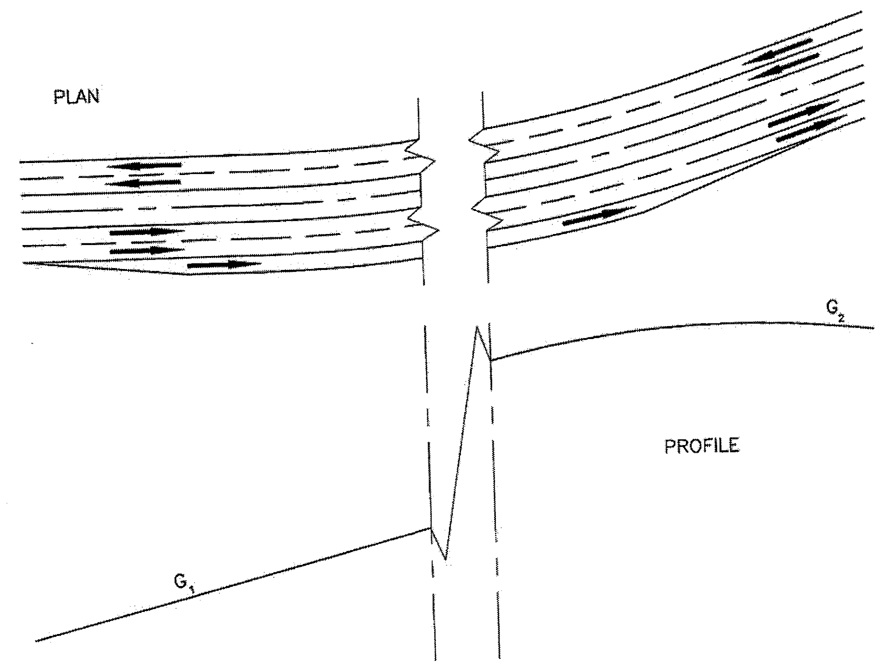

Exhibit 3-62. Climbing Lane on Freeways and Multilane Highways

Methods for Increasing Passing Opportunities on Two-Lane Roads

Several highway agencies have pioneered successful methods for providing more passing opportunities along two-lane roads. Some of the more recognized of these methods, including passing lanes, turnouts, shoulder driving, and shoulder use sections are described in the FHWA informational guide *Low Cost Methods for Improving Traffic Operations on Two-Lane Roads* (**42**). A synopsis of portions of material found in this guide pertaining to these designs is presented in the succeeding sections. More detailed criteria for these methods are found in the guide.

Passing Lanes

An added lane can be provided in one or both directions of travel to improve traffic operations in sections of lower capacity to at least the same quality of service as adjacent road sections. Passing lanes can also be provided to improve overall traffic operations on two-lane

highways by reducing delays caused by inadequate passing opportunities over significant lengths of highways, typically 10 to 100 km [6 to 60 miles]. Where passing lanes are used to improve traffic operations over a length of road, they frequently are provided systematically at regular intervals.

The location of the added lane should appear logical to the driver. The value of a passing lane is more obvious at locations where passing sight distance is restricted than on long tangents that may provide passing opportunities even without passing lanes. On the other hand, the location of a passing lane should recognize the need for adequate sight distance at both the lane addition and lane drop tapers. A minimum sight distance of 300 m [1,000 ft] on the approach to each taper is recommended. The selection of an appropriate location also needs to consider the location of intersections and high-volume driveways in order to minimize the volume of turning movements on a road section where passing is encouraged. Furthermore, other physical constraints such as bridges and culverts should be avoided if they restrict provision of a continuous shoulder.

The following is a summary of the design procedure to be followed in providing passing sections on two-lane highways:

1. Horizontal and vertical alignment should be designed to provide as much of the highway as practical with passing sight distance (see Exhibit 3-7).
2. Where the design volume approaches capacity, the effect of lack of passing opportunities in reducing the level of service should be recognized.
3. Where the critical length of grade is less than the physical length of an upgrade, consideration should be given to constructing added climbing lanes. The critical length of grade is determined as shown in Exhibits 3-59 and 3-60.
4. Where the extent and frequency of passing opportunities made available by application of Criteria 1 and 3 are still too few, consideration should be given to the construction of passing-lane sections.

Passing-lane sections, which may be either three or four lanes in width, are constructed on two-lane roads to provide the desired frequency of passing zones or to eliminate interference from low-speed heavy vehicles, or both. Where a sufficient number and length of passing sections cannot be obtained in the design of horizontal and vertical alignment alone, an occasional added lane in one or both directions of travel may be introduced as shown in Exhibit 3-63 to provide more passing opportunities. Such sections are particularly advantageous in rolling terrain, especially where alignment is winding or the profile includes critical lengths of grade.

In rolling terrain a highway on tangent alignment may have restricted passing conditions even though the grades are below critical length. Use of passing lanes over some of the crests provides added passing sections in both directions where they are most needed. Passing-lane sections should be sufficiently long to permit several vehicles in line behind a slow-moving vehicle to pass before returning to the normal cross section of two-lane highway.

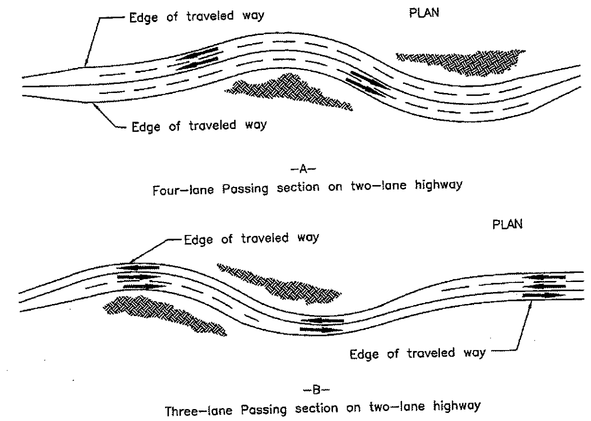

Exhibit 3-63. Passing Lanes Section on Two-Lane Roads

A minimum length of 300 m [1,000 ft], excluding tapers, is needed to assure that delayed vehicles have an opportunity to complete at least one pass in the added lane. Where such a lane is provided to reduce delays at a specific bottleneck, the needed length is controlled by the extent of the bottleneck. A lane added to improve overall traffic operations should be long enough, over 0.5 km [0.3 mi], to provide a substantial reduction in traffic platooning. The optimal length is usually 0.8 to 3.2 km [0.5 to 2.0 mi], with longer lengths of added lane appropriate where traffic volumes are higher. The HCM (**14**) provides guidance in the selection of a passing lane of optimal length. Operational benefits typically result in reduced platooning for 5 to 15 km [3 to 10 miles] downstream depending on volumes and passing opportunities. After that, normal levels of platooning will occur until the next added lane is encountered.

The introduction of a passing-lane section on a two-lane highway does not necessarily involve much additional grading. The width of an added lane should normally be the same as the lane widths of the two-lane highway. It is also desirable for the adjoining shoulder to be at least 1.2 m [4 ft] wide and, whenever practical, the shoulder width in the added section should match that of the adjoining two-lane highway. However, a full shoulder width is not as needed on a passing lane section as on a conventional two-lane highway because the vehicles likely to stop are few and there is little difficulty in passing a vehicle with only two wheels on the shoulder. Thus, if the normal shoulder width on the two-lane highway is 3.0 m [10 ft], a 1.8- to 2.4-m [6- to 8-ft] widening of the roadbed on each side is all that may be needed.

Four-lane sections introduced explicitly to improve passing opportunities need not be divided because there is no separation of opposing traffic on the two-lane portions of the highway. The use of a median, however, is advantageous and should be considered on highways carrying a total of 500 vehicles per hour or more, particularly on highways to be ultimately converted to a four-lane divided cross section.

The transition tapers at each end of the added-lane section should be designed to encourage safe and efficient operation. The lane-drop taper length should be computed from the MUTCD (**6**) formula $L = 0.6WS$ (L = Length in meters, W = Width in meters, S = Speed in km/h) or

$L = WS$ [L = Length in ft, W = Width in ft, S = Speed in mph] while the recommended length for the lane addition taper is half to two-thirds of the lane-drop length.

The signing and marking of an added lane is partially addressed in the MUTCD (**6**), which indicates the appropriate centerline markings for such lanes as well as the signing and marking of lane drop transitions. However, the MUTCD (**6**) does not address signing in advance of and at the lane addition. A sign with the legend "Passing Lane 1 Kilometer" ["Passing Lane 1/2 Mile"] should be placed in advance of each added lane in order that drivers of both slow-moving vehicles and following vehicles can prepare to make effective use of the added lane. Additional signs 3 to 10 km [2 to 5 mi] in advance are also desirable because they may reduce the frustration and impatience of drivers following a slow-moving vehicle by assuring them that they will soon have an opportunity to pass. In addition, a sign should be installed at the beginning of the lane addition taper to encourage slower moving vehicles to keep right.

The transitions between the two- and three- or four-lane pavements should be located where the change in width is in full view of the driver. Sections of four-lane highway, particularly divided sections, longer than about 3 km [2 mi] may cause the driver to lose his sense of awareness that the highway is basically a two-lane facility. It is essential, therefore, that transitions from a three- or four-lane cross section back to two lanes be properly marked and identified with pavement markings and signs to alert the driver of the upcoming section of two-lane highway. An advance sign before the end of the passing lane is particularly important to inform drivers of the narrower roadway ahead; for more information, see the MUTCD (**6**).

Turnouts

A turnout is a widened, unobstructed shoulder area that allows slow-moving vehicles to pull out of the through lane to give passing opportunities to following vehicles (**42, 43**). The driver of the slow-moving vehicle, if there are following vehicles, is expected to pull out of the through lane and remain in the turnout only long enough for the following vehicles to pass before returning to the through lane. When there are only one or two following vehicles, this maneuver can be accomplished without it being necessary for the driver of the vehicle in the turnout to stop. However, when this number is exceeded, the driver may need to stop in the turnout in order for all the following vehicles to pass. Turnouts are most frequently used on lower volume roads where long platoons are rare and in difficult terrain with steep grades where construction of an additional lane may not be cost-effective. Such conditions are often found in mountain, coastal, and scenic areas where more than 10 percent of the vehicle volumes are large trucks and recreational vehicles.

The recommended length of turnouts including taper is shown in Exhibit 3-64. Turnouts shorter than 60 m [200 ft] are not recommended even for very low approach speeds. Turnouts longer than 185 m [600 ft] are not recommended for high-speed roads to avoid use of the turnout as a passing lane. The recommended lengths are based on the assumption that slow-moving vehicles enter the turnout at 8 km/h [5 mph] slower than the mean speed of the through traffic. This length allows the entering vehicle to coast to the midpoint of the turnout without braking, and then, if necessary, to brake to a stop using a deceleration rate not exceeding 3 m/s^2 [10 ft/s^2].